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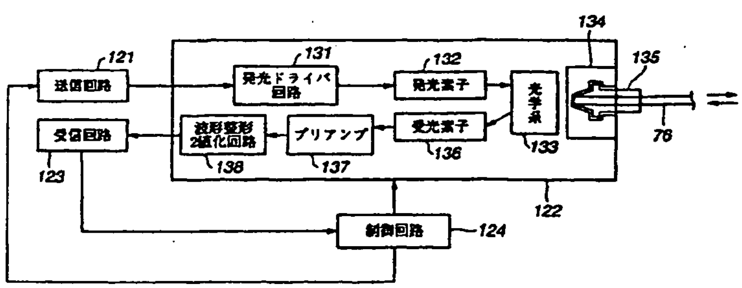
(54) Title: OPTICAL COMMUNICATION APPARATUS AND COMMUNICATION METHOD

(54) 発明の名称: 光通信装置及び通信方法



121...TRANSMITTING CIRCUIT
123...RECEIVING CIRCUIT
124...CONTROL CIRCUIT
131...LIGHT EMISSION DRIVER CIRCUIT
132...LIGHT EMITTING ELEMENT
133...OPTICAL SYSTEM
136...LIGHT RECEIVING ELEMENT
137...PREAMPLIFIER
138...WAVEFORM-SHAPING BINARIZING CIRCUIT

(57) Abstract: An optical communication apparatus using a single optical fiber to effect a two-way communication at the same time. A light emitting element (132) emits its generated light through an optical system (133) to an optical fiber (76). A light having been transmitted through the optical fiber (76) is received by a light receiving element (136) via the optical system (133). The optical system (133) is set such that the value of the light amount M of stray light is given as follows: $S - 2QN \geq M > S / 2Q - N$ where Q is the value of the Q value representing a required communication quality, S is the light amount of a received signal from the other end of communication, and N is the total sum of Gaussian noise.

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"OP i. LINK: Optical Transmission Technology to Connect 10m by IEEE1394", ***Nikkei Electronics*****, December 4, 2000 edition (No. 784) (published on December 4, 2000), pp. 167-176**

A. Relevance of the Above-identified Document

This document has relevance to all claims of the present application.

B. Translation of the Relevant Passages of the Document

Optical Crosstalk Test

In OP i. Link, which realizes transmission over 10m at maximum using a single-fiber POF, the communication method used is not the half-duplex method, but the full-duplex method. This is because the half-duplex method, which cannot ensure a sufficient hop number, makes it difficult to build a network (see pp. 172-173, "Full-Duplex Method and 8B/10B Encoding Adopted in Favor of Hop Number and DC Balance").

However, there is one problem in performing optical communication using a single-fiber POF by the full-duplex method: the problem of optical crosstalk, i.e. the problem that an optical output from an optical transceiver is reflected into the light-receiving element (photodiode) of the own port. The noise generated by the optical crosstalk

deteriorates the BER (bit error rate) of data transmission. Therefore, tests were conducted to find out whether or not the noise generated by the optical crosstalk satisfies the requirement of the specification of OP i. Link. The following describes what was examined.

Minimum Crosstalk: 6.0dB

According to the specification of OP i. Link, the phase margin in the waveform of the received light transmitted from the optical transceiver to the physical-layer LSI is $BER<10^{-12}$, 3.5ns or more. These values are less strict than the values required by P1394b and the like. This is aimed at reducing product prices by making it possible to use generally used PLL (phase-locked loop), which can be obtained at low prices.

The condition that satisfies the requirement of the specification of OP i. Link was calculated. The eye pattern in the full-duplex transmission using a single-fiber POF was modeled, and the condition that satisfies $BER<10^{-12}$ was calculated (Fig. 3). According to the result, it is necessary to satisfy $(A/\sigma)>19$, where A is the amplitude of the received light, and σ is the distribution of Gaussian noise. Based on this relationship, simulations and experiment data analysis were conducted. As a result, it was found that the amplitude X of the optical crosstalk

needs to be 1/4 or lower with respect to the amplitude A of the received light. That is, the specification of OP i. Link requires that the ratio (optical crosstalk ratio) between the received light and the optical crosstalk be 6.0dB or larger.

Test of 10m Transmission Distance

Next, based on the light-amount budget, it was examined whether or not the optical crosstalk ratio equal to or larger than 6.0dB can be ensured when the transmission distance of the optical transmission by full-duplex method is 10m. In examining the light-amount budget, used was the model in which optical transceivers using LEDs or semiconductor lasers as light sources are connected to both ends of a 10m POF, respectively (Fig. 4).

In order to examine the light-amount budget under the condition that maximizes the amount of optical crosstalk (that is, under the worst condition), the power of the light source was set as follows, according to the specification of OP i. Link: minimum value: -10.9dBm, maximum value: -2.7dBm, and production tolerance: Δ8.2dB. These values are experimental values considering the production tolerance and deterioration over time of the LEDs available at low process by mass production. As

for the communication between the LEDs and semiconductor lasers, it is sufficient if the condition based on these experimental values of the LEDs is considered. This is because the power of the semiconductor laser can be controlled by APC (auto power control).

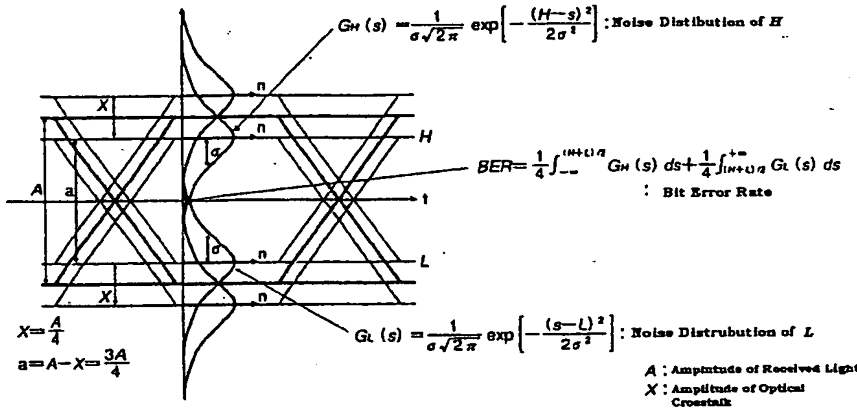
In order to examine the light amount budget, calculated with respect to the light received by the photodiode of the optical transceiver were (1) the minimum amount of the received light, (2) the maximum amount of the optical crosstalk caused by far-end reflection, and (3) the maximum amount of the optical crosstalk caused by near-end reflection. The near-end reflection is the reflection which occurs in the own optical transceiver, and the far-end reflection is the reflection which occurs in the optical transceiver connected thereto. Because the minimum power of the other port was –10.9dBm, the maximum transmission loss in the 10m POF was –5.6dB, and the loss in the receiving optical system in the optical transceiver was –7.0dB, (1) the minimum amount of the received light was –23.5dBm. Next, (2) the maximum amount of the optical crosstalk caused by the far-end reflection was calculated. The output of the own port (maximum power: –2.7dBm) was reduced by the minimum transmission loss (–2.3dB) in the

10m POF, and was −5.0dBm when received by the optical transceiver of the other port. The reflected light (−23.5dBm) generated by the far-end reflection was reduced again by the minimum transmission loss (−2.3dB) of the POF and by the loss (−7.0dB) in the receiving optical system in the optical transceiver, and was received by the photodiode. That is, (2) was −32.8dBm. Due to the transmitted light (−2.7dBm) from the own port and the near-end reflection, (3) the maximum value of the optical crosstalk caused by the near-end reflection was −32.7dBm.

In summary, the minimum value of the received light was −23.5dBm, and the maximum amount of the optical crosstalk was −29.7dBm, which was the sum of (2) and (3). As a result, when the transmission distance of the POF was 10m, the optical crosstalk ratio was 6.2dB at maximum. Thus, it was confirmed that, when the transmission distance is 10m, the optical crosstalk ratio satisfies 6.0dB, which is the value required by OP i. Link.

Fig. 3 Model of Eye Pattern Including Optical Crosstalk

The eye pattern under the presence of optical crosstalk was modeled, and the condition that satisfies BER (bit error rate) $<10^{-12}$ was calculated. According to the result of calculation, it is necessary to satisfy $(A/\sigma)>19$, where A is the amplitude of the received light, and σ is the distribution of Gaussian noise, such as amplification noise of the receiving circuit (Fig.: Sonny and Sharp).



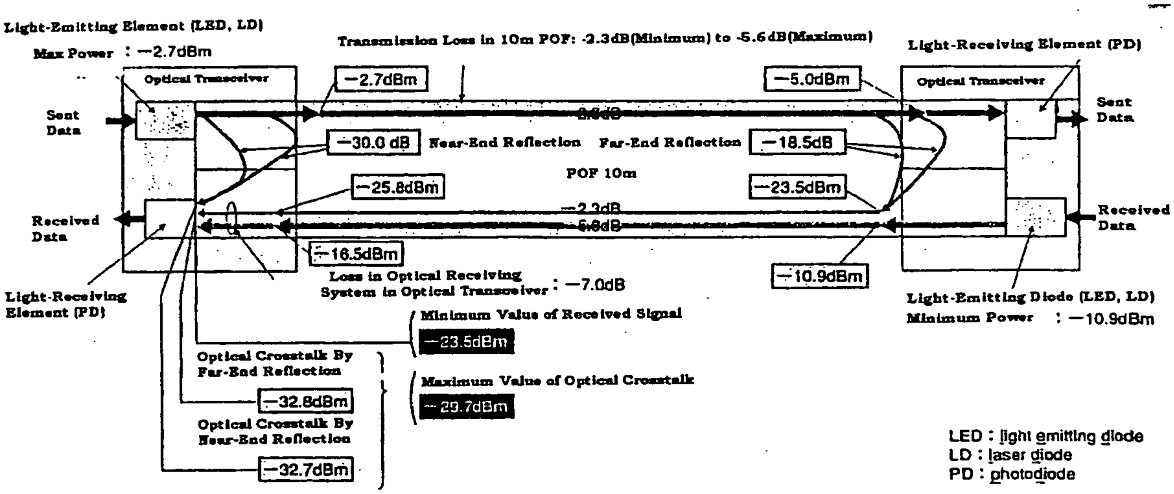


Fig. 4 Optical Crosstalk and Light-Amount Budget
When optical transmission is performed by full-duplex method using a single-fiber POF, optical crosstalk is caused by near-end reflection and far-end reflection. The light-amount budget was examined considering the optical crosstalk. This figure illustrates an example where the light-amount budget was examined under the condition that optical transceivers were connected to both ends of a 10m POF, respectively, the optical transceivers using LEDs or semiconductor lasers as light-emitting elements. The minimum value of the received signal was -23.5 dBm, and the maximum amount of optical crosstalk was -29.7dBm.